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BIOENGINEERING PROBLEMS OF HABITABILITY OF SPACECRAFT AND PLANETARY STATIONS

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BIOENGINEERING PROBLEMS OF HABITABILITY OF SPACECRAFT AND PLANETARY STATIONS 1*

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The future development of rocket engineering and cosmonautics provides for planned conquest of cosmic space and of the solar system planets closest to Earth. In this connection the duration of space flights will be extended and this imposes special conditions with respect to development of medicobiological provisions.

The main problem with respect to medicobiological provisions for space flights is the creation of the necessary conditions that would permit the crew of a spacecraft or planetary station to perform the flight or expedition program sucessfully with a high degree of reliability.

Medicobiological safety of any space flight implies the need to solve the following basic problems:

- development and effectuation of rational preparation of man for the flight;
- determination of man's physiological reactions to extreme factors of flight;
- determination of permissible range of fluctuation of sanitary-hygienic characteristics of the inhabited environment and physiological indices in relation to the norm under different space flight conditions;
- development and creation of means providing for vital activity and high degree of efficiency of the crew throughout the flight.

The last two items are of special significance since they ultimately 2
determine the requirements with respect to implementation of medicobiological safety of space flights. These two items are essentially the main components of the science of habitability of spacecraft and planetary stations.

In order to fulfill successfully the flight program in a sealed and restricted cabin first of all a favorable environment must be created.

The environmental conditions required by man in the cabin are maintained by a complex life support system for the crew of a complex spacecraft or planetary station.

The life support complex provides the crew with the following:

- nutrients (proteins, fats, carbohydrates, cellulose, vitamins, salts, etc) in a quantity of about 700 grams/man per day;
- pure drinking water in a quantity of about 2200 grams/man daily;
- oxygen in a quantity of about 800 grams/man daily.

*Numbers in the margin indicate pagination in the original foreign text.

The life support systems remove from the cabin the gas, fluid and solid products of man's vital activity and provide for sanitary-hygienic treatment of the cabin and man. 2

The concentrations of carbon dioxide and harmful admixtures in the cabin atmosphere are maintained at maximum permissible levels.

Comfortable conditions are provided in the cabin for working, sleeping, and eating.

Air temperature is maintained at the permissible level by means of a system of thermoregulation and air conditioning. 3

There are also provisions for protection of the crew from cosmic radiations, systematic monitoring and transmission to Earth of data on the health of the cosmonauts.

The complex of life support systems for cosmonauts is so designed that the total weight of the life support systems, including the weight of the expendable foods stored on board would be at a minimum. For this, of the many means that could be used to solve the problem set forth, that of providing normal living and working conditions in the cabin, only those are selected that permit creating the lightest systems for the spacecraft or station for the assigned number of crew members and duration of flight or expedition.

Oxygen supply can be provided in relation to duration of the flight:

1. By providing on board supplies of gas or liquid oxygen or a supply of substances that contain oxygen (for example, hydrogen peroxide or peroxide compounds of alkaline metals);

2. By using systems of oxygen regeneration from carbon dioxide exhaled by man.

For regeneration the following can be used:

- the method of direct decomposition of carbon dioxide;
- the method of catalytic reduction of carbon dioxide to carbon and water and subsequent decomposition of the water formed by electric current. 4

3. By using plants as sources of oxygen and carbon dioxide absorbers.

Water can be supplied:

1. On the basis of providing a supply of drinking water on board;

2. By regeneration of water from the liquid products of man's vital activity (by distillation, catalytic purification, sorption purification on ion exchangers, etc). 4

Food can be stored on board in dehydrated form; in addition it is possible to have complexes in which:

- the plant component of the ration is obtained by cultivating algae on board the spacecraft or station and cultivation of vegetables without soil;
- animal proteins are obtained from lower or higher animals maintained on the craft.

There are also other means of meeting the demands of cosmonauts with respect to oxygen, water and food.

It must be borne in mind that the final selection of life support systems to solve a concrete problem can be made only after a comprehensive estimation of energy and weight capabilities of the rocket system and craft or planetary station, solving the problem of optimum 5
biological and engineering characteristics, and, finally, after conducting prolonged experiments with the participation of man in a closed space under conditions simulating those of a space flight. The latter permits offering recommendations pertaining to permissible fluctuations of sanitary-hygienic parameters of the environment and physiological indices as well as development of the needed measures providing a high degree of reliability of system operation, high efficiency of the crew, which would undoubtedly help in the successful performance of the flight program, which usually includes a complex set of physico-engineering and medico-biological tests, and will increase the safety.

The use of information about the crew for "optimization" of processes, characteristics and their regulation requires first of all that effective methods be created for collecting and processing such information.

This requires first of all the development of algorithms of automatic medical and bioengineering monitoring, automatic decoding of physiological and engineering information, automatic diagnosis and prognosis of man's condition and of any other link in the complex of life support systems.

It must be borne in mind that a man inhabiting an artificially created environment is at the same time the most objective indicator of the efficiency of the elements forming the environment. It is practically impossible to create such a system of centralized monitoring that would permit detection of the slightest changes in concentration of substances that are present in negligible quantities in the gas phase. At 6
the same time, precisely microquantities of some complex chemical compounds

can influence appreciably the environment, and, when man remains in such an environemnt for a long period of time, this will inevitably lead to visible changes in vital systems of the human organism. For this reason any complex of life support systems can earn approval only after prolonged investigation and tests with the participation of man. 6

Of special significance in such prolonged tests of bioengineering life support systems is the study of compatibility of the different links in the systems.

In developing life support systems it is also necessary to bear in mind that man's life on board a spacecraft or planetary station proceeds under conditions of an altered environment. Its most distinctive features are the lack of or low gravity, presence of a constant background of galactic cosmic radiation which is visibly greater than on Earth, and, finally, a set of factors arising as a result of a prolonged stay in a sealed space of restricted size. In the latter case changes in chemical composition of the air, increase in aeroion, ozone nitrogen oxide concentration, probable changes in isotope composition of oxygen and nitrogen that could develop under the effect of cosmic radiation, and increase in bacterial contamination of the environment with possible change in properties of microorganisms acquire special significance.

Under these specific conditions changes occur in practically all of the systems of the human organism, which is definitely proven by tests conducted under space flight conditions and in earthbound stand tests. Most typical are changes in metabolic processes, neurohumoral regulation, motor analzyer and cardiovascular system. The changes observed characterize the complex process of the organism's adaptation to new living conditions, different from those on Earth. Adaptation leads to the formation of a new level of human organism functioning, corresponding to concrete living conditions. 7

At the same time a number of changes are detected which are the reaction of the organism to the effect of adverse or deleterious factors of flight and cosmic space. In view of this it is necessary to provide as complete purification of air as possible from noxious admixtures, and to normalize the quantitative and qualitative composition of the microflora. In addition, in creating life support systems as a whole or their individual elements, consideration must be given to their safety and, which is particularly important, their compatibility with man.

On the basis of these positions it may be concluded that the creation of effective and optimum life support systems for man is possible only through a process of creative collaboration of medics and biologists with designers of spacecrafts and their individual systems. We must stress the importance and fundamental necessity of participation of representatives of medicine and biology in designing space objects at all stages, since the creation of any habitable space object is the result of a search for a rational compromise between present engineering

capabilities and man's physiological and hygienic requirements. In this respect, determination of permissible levels of exposure to adverse and deleterious factors merits special attention. On the basis of general principles it is necessary to furnish recommendations for concrete space objects, taking into consideration as the minimum two main aspects: duration of the flight or stay on a planetary station and the uniqueness of the problems facing the crew. In each concrete case the permissible levels should be determined in relation to at least the time and complexity of the problem set forth for the crew of the space object. One should also bear in mind the possibility of selective change in reactivity of the human organism for the purpose of increasing its resistance to adverse factors both during preparation and flight. 8

Of course the factors discussed are far from exhausting all of the bioengineering problems referable to habitability of spacecraft and planetary stations.

And even with respect to the problems discussed in this report, our knowledge is still quite inadequate to describe completely this extremely important problem of medicobiological safety of space flights.

All this points to the urgent need of extensive development of scientific research on habitability of spacecraft cabins both on Earth and under flight conditions, and of further strengthening of collaboration of biology, medicine and technology in the matter of conquering cosmic space.